Optimizing Portability of a Mine Scour/Burial Model by Means of a Geomorphic Coastal Classification System

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LONG-TERM GOALS

Our overall objectives are to develop a process oriented model for the prediction of scour, burial, and station keeping of mines and neutralization devices deployed in the shallow waters of the global coastal zone; and to place this model, complete with code and descriptive text, in the Ocean/Atmosphere Model Library (OAML). To provide global capability, we developed a classification system that orders world coastal diversity into categories that optimize the portability of the model.

OBJECTIVES

The basic scientific objective is to determine the appropriate geomorphic principles and processes by which world coastal diversity may be ordered into a set of distinct coastal types. The applied objective is to use the coastal classification system to optimize the portability of an upgraded version of the Vortex Lattice Model (Figure 1). The following research goals, applicable to each coastal type, are set forth to satisfy these objectives: 1) Develop a database for the geomorphic coastal classification scheme that establishes ranges of natural variability of the model input parameters; 2) develop gridding schemes for the farfield and near field of the model that are specific to; 3) configure forcing function interfaces and databases; 4) perform sensitivity and error propagation analysis of scour, burial and station keeping response; 5) identify leading order scour, burial and station keeping parameters; 6) prepare model for library acceptance.

APPROACH

Our approach to portability is to apply a classification system to the world's coastlines that is sensitive to the morphological and sedimentary characteristics of the coast. Our coastal classification scheme is

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14. ABSTRACT
Our overall objectives are to develop a process oriented model for the prediction of scour, burial, and station keeping of mines and neutralization devices deployed in the shallow waters of the global coastal zone; and to place this model, complete with code and descriptive text, in the Ocean/Atmosphere Model Library (OAML). To provide global capability, we developed a classification system that orders world coastal diversity into categories that optimize the portability of the model.

15. SUBJECT TERMS

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a modified version of the tectonic/geomorphic classification of Inman and Nordstrom (1971; Davis, 1996) referred here as the “geomorphic coastal classification”. This system is embedded in the architecture of the Vortex Lattice Model through a system of logic networks (Figure 1, beige colored module) and establishes common sets of input parameters, forcing functions, and gridding schemes for each coastal class so that coastal diversity does not present an infinite number of model initialization problems. The coastal classification system provides a framework for assessing the predictive skill of the model. The natural range of variability associated with a particular coastal class establishes the error bounds of input parameters and the precision of forcing functions and boundary conditions. Error propagation is limited by means of data adaptive loops (indicated in red in Figure 1) which can make iterative corrections to model parameters for a particular coastal type. These error propagation and data adaptive analyses provide the most critical geomorphic parameters in the scour/burial processes for each coastal class and thereby provide insight for mine warfare tactics as well as a rational system of rules for implementation in an Expert System Modeling approaches to the burial problem.

WORK COMPLETED

Our progress towards the above objectives has been considerable. We have developed a Vortex-Lattice Model that is adaptable to any size and shape object; successfully modeled rates of scour and burial of diverse shapes, successfully modeled migration rates under certain conditions and are readying the preliminary version of our model for inclusion in OAML.

The model has been coded for farfield mine burial/exposure associated with (a) seasonal profile changes, (b) divergence of the drift due to wave climate change (Figure 2a), and (c) sediment budget changes due to sediment flux of rivers. We have calibrated and validated the farfield burial algorithms of the model for the effect of seasonal profile changes off Scripps Pier (Figure 2b). We have calibrated and validated the near field scour, burial and station keeping algorithms for MANTA, and VSW Marker (Figure 3) and have performed sensitivity and error damping analyses of the model, achieving significant improvement in controlling error propagation through the use of data adaptive loops (indicated in red in Figure 1).

We have developed a coastal classification for the synthesis of model input parameters. For a given coastal type a range of common boundary conditions, sedimentary, hydrodynamic, and transport factors were identified and structured in a system of Bayesian networks to produce selections of model parameters and gridding schemes shown schematically by the beige oval shaped module in Figure 1. The use of such logic networks to initialize the model according to coastal type was studied by sensitivity analysis.

We have evaluated the sensitivity of mine burial to wave climate, bed roughness and grain size. We have illustrated the numerical capability of the model by accurately predicting the station keeping of the VSW mine neutralization marker (explosive package) delivered by porpoise (Figure 3). We have demonstrated that the model can accurately predict the time for which the neutralization marker would remain on station (station keeping time) near a mine placed in coastal waters off San Diego, CA. These results have been extrapolated to other regions of the world using model parameters (roughness, grain size) derived from our coastal classification system (Figure 4).

RESULTS

Our field measurements and model sensitivity analyses determined that wave climate, bed roughness and sediment grain size are the leading order factors controlling mine burial rates. Scour/burial rates were found to increase with increasing wave energy and bed roughness and decrease with increasing grain size. Wave climate and sediment supply further modulate burial rates through farfield adjustments in bottom elevation (Figure 2b). These wave climate, roughness and sediment factors are related to model parameters such as closure depth h_c, drag coefficient c_f, transport efficiency ε, and bedform height η, and can be bounded within characteristic limits according to coastal classification.

The classification includes three general tectonic types of coasts (and their morphologic equivalents and two types associated with latitudinal extremes: 1) collision coasts with narrow shelves and steep coastal topography resulting from collisions between two or more tectonic plates; 2) trailing-edge coasts that are on the stable, passive margins of continents with broad shelves and low inland relief; 3) marginal sea coasts that are semi-enclosed by island arcs and thereby fetch limited; 4) cryogenic coasts that are affected by ice processes; and, 5) biogenic coasts that are formed by fringing coral reefs or mangroves, etc.

The morphology of these coastal types sets fairly well defined limits on the dimensions of the littoral cells within a particular coastal type and thereby establishes a natural ordering for the farfield length scales in the model. For example, the collision and coral reef coasts have relatively steep bottom gradients with small cross-shore dimensions and a high degree of longshore compartmentalization caused by coastal headlands. This leads to fairly compact farfield grid domains with grid resolution set for long fetch, high energy waves. This in turn dictates relatively deep closure depths h_c (depth of vanishing net on-offshore transport of sediment). In contrast, marginal seas are fetch limited and the resulting short period waves dictate small grid scales and shallow closure depths. The closure depth, h_c was found to be a particularly critical parameter in error propagation. Error damping through iterative adjustments to h_c, using data adaptive loops (Figure 1), was found to be extremely effective in predicting farfield burial induced by profile changes from seasonal wave climate (Figure 2).

The wave climate dependence of mine burial rate is modified by the range of variation in bed roughness. For a MANTA mine at 7 m depth along a collision coast, bed roughness variations of 0.5 to 3 cm can produce variations of 60% in burial rate of the mine. For cryogenic coasts where ice gouging in the Stamukhi zone create bed roughness of 0(1-2 m), mine burial or exposure could be instantaneous, although episodic. For lower energy environments in marginal seas where strong tidal currents are absent, and bed roughness is small, the scour and burial rates can be one to two orders of magnitude less than the collision coast.

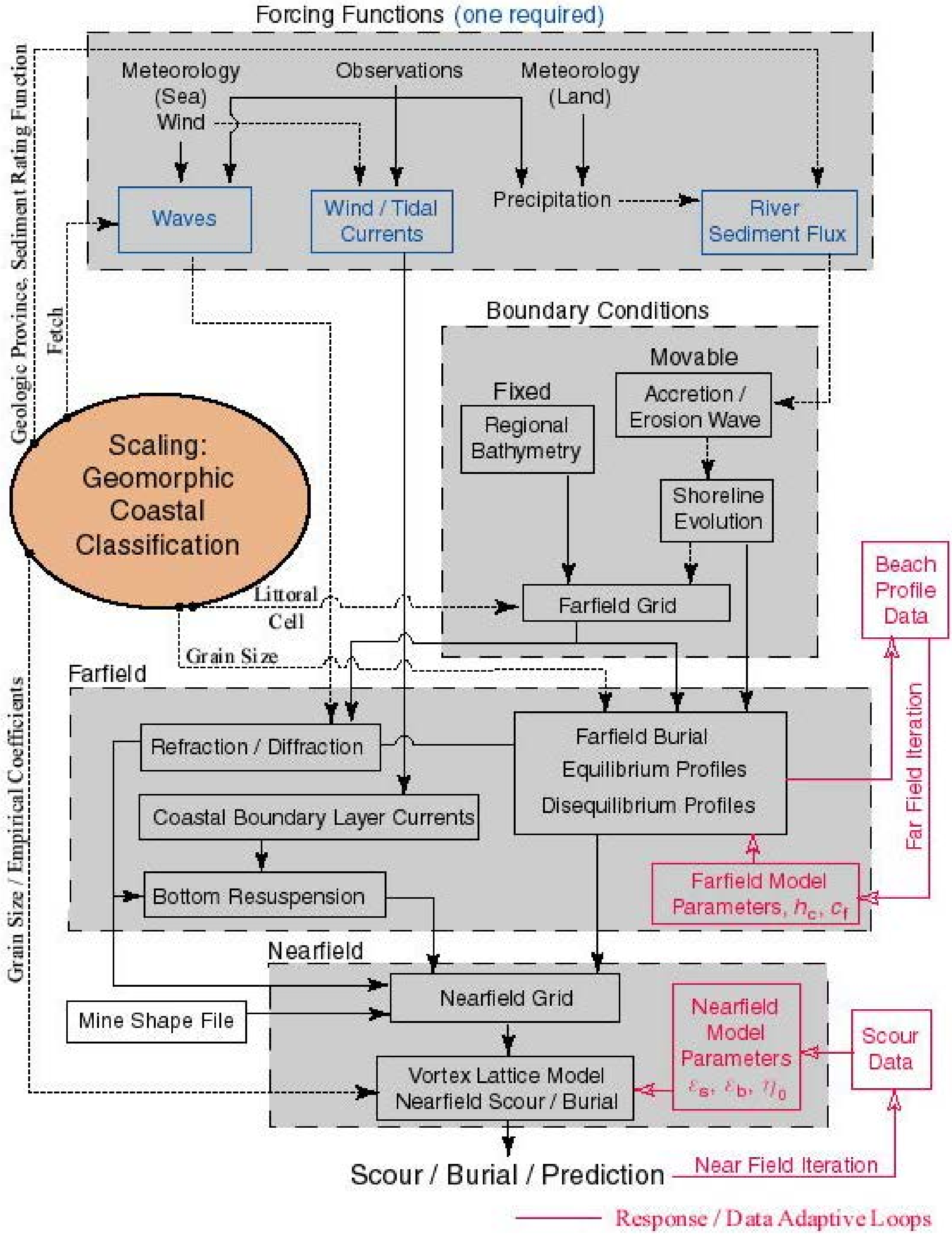

Figure 1. Architecture of the Vortex Lattice Model with geomorphic coastal classification networks for the synthesis of model input parameters.

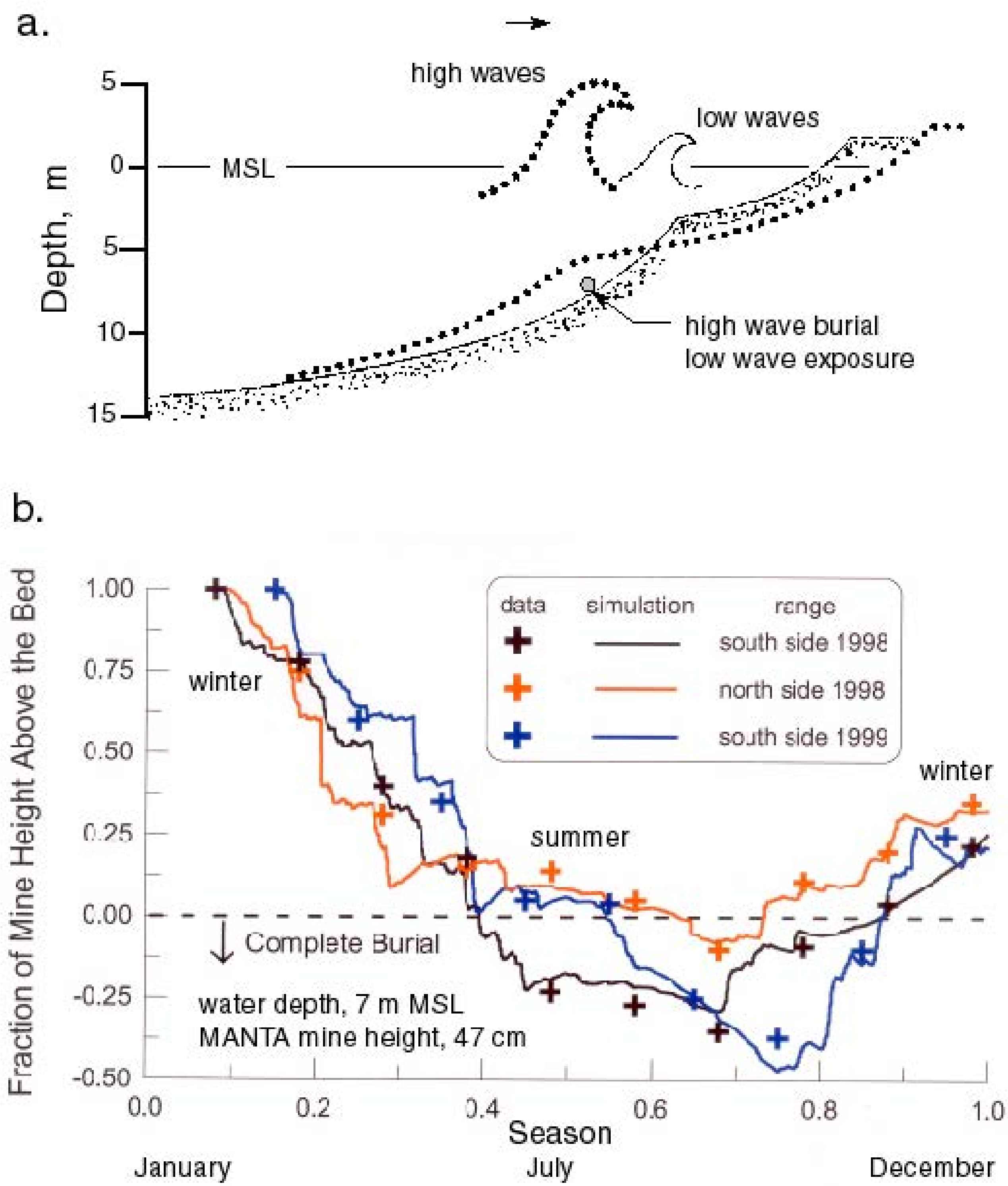

Figure 2. (a) Beach profile changes due to seasonal wave climate and/or net decrease/increase in source material. (b) Burial and exposure of two MANTA mines associated with seasonal profile changes off Scripps Pier. Solid line is model simulation, "+" are field observations.

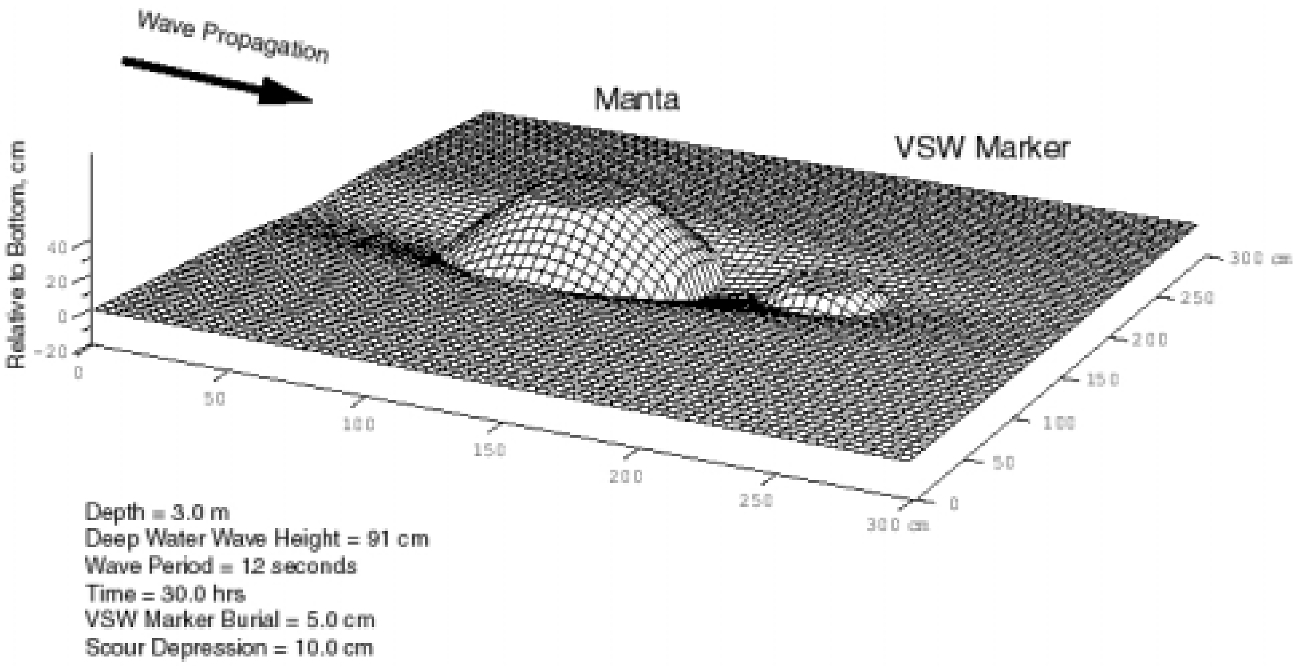

Figure 3. Model simulation of the nearfield scour / burial interaction of a MANTA mine and the VSW Neutralization Marker.

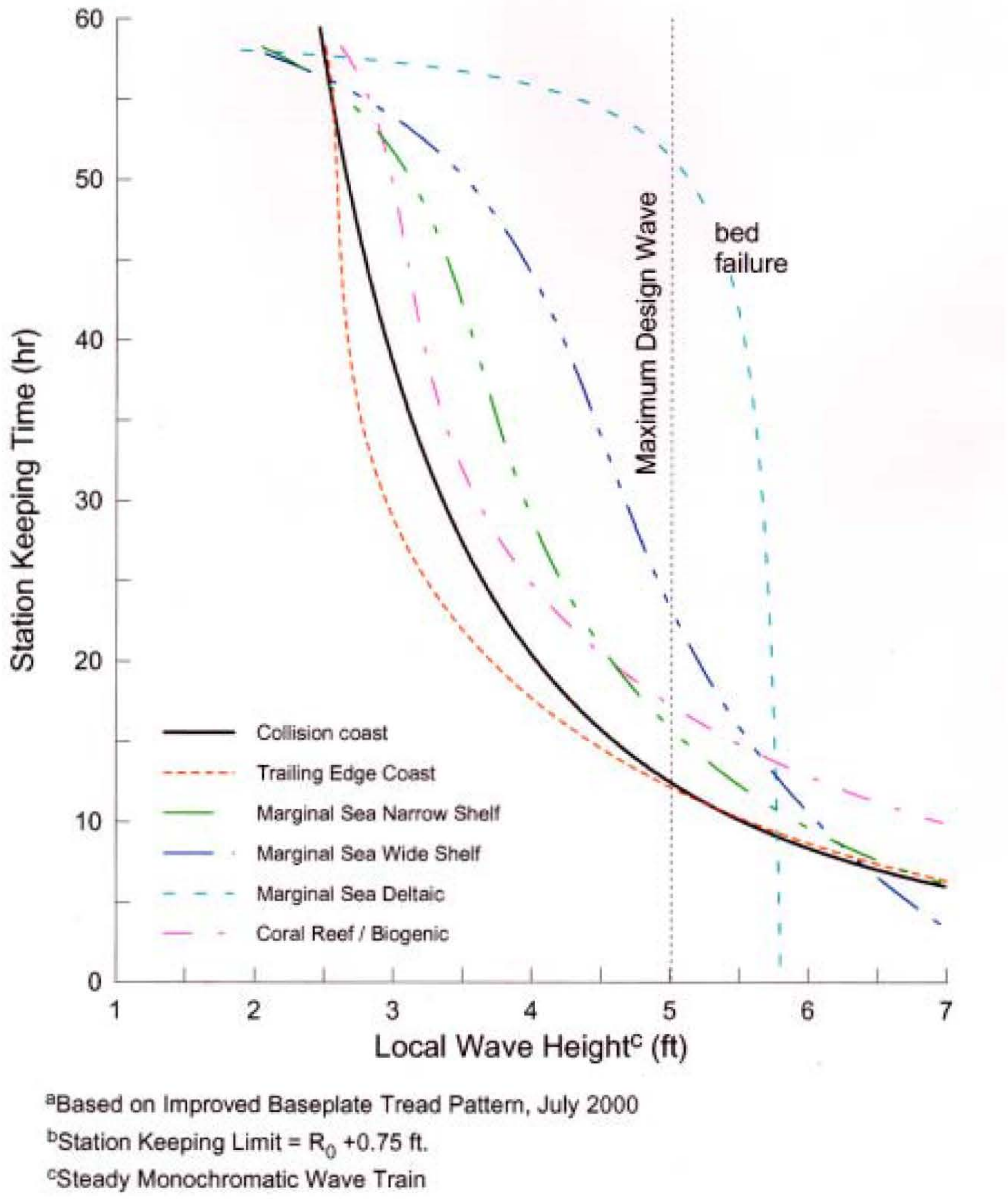

Figure 4. Station keeping time for VSW Neutralization Marker as a function of coastal type, immersed weight, 13 pounds, water depth, 10 feet, acoustic tether length, 3 feet.

The sources and sinks of sediment for a particular coastal type exert a strong influence on the sediment size. Longshore and cross-shore variations in grain sizes are caused by waves and currents and control the bed roughness. The maximum rate of scour/burial of a MANTA varies with the median grain size and with the degree of sorting of the sediment. For coarser sands typical of the relict glacial deposits of a trailing-edge coast like at Duck, NC, the scour/burial rate for a particular incident wave is about an order of magnitude less than for the fine sand of a high relief collision coastline such as La Jolla, CA. For poorly sorted, newly-deposited deltaic sediments as found on a marginal sea coast, the scour/ burial rate can vary by 50%-80% depending on the standard deviation of the grain size distribution.

The burial rate characteristics as a function of coastal type also translate into the station keeping of mine neutralization devices such as the VSW Marker (Figure 3). Progressive scour/burial arrests migration of an object. Coastal types with intrinsically slow scour/burial rates, associated with bed roughness and grain size, afford relatively poor station keeping for a given wave height. The Vortex Lattice Model was used to give design guidance on the expected station keeping performance over a diverse range of coastal deployment. We show in Figure 4 that the fetch limited fine-grained sedimentary environments of deltaic and wide- shelf marginal seas provide several days of station keeping time while the coarser grained, long fetch environments of collision and trailing-edge coasts afford less than a day.

IMPACT/APPLICATIONS

The geomorphic coastal classification system provides a rational framework for organizing world coastal diversity into a manageable number of discrete categories. This can provide a powerful management and decision making tool for resource agencies as well as for the mine warfare community. With respect to the latter, the mix of tactics which the VSW detachment is likely to use in a mine threat environment is strongly effected by many of the morphology and seabed properties which this system organizes. Therefore our coastal classification system is a logical adjunct to the Mine Warfare Environmental Decision Aids Library (MEDAL) and could be used to systematize the databases within MEDAL and the doctrine around it.

RELATED PROJECTS

The Vortex Lattice Scour/Burial Model has been used as a design tool in the development of the VSW Neutralization Marker for the Marine Mammal Systems Branch, SPAWAR, Code D352, San Diego. The model results for the VSW marker were used in the preparation of the Weapons System Explosive Safety Review Board (WSESRB) documents. In addition, sensitivity analysis of the model is being applied to a variety of pre- and post-assault scenarios in support of efforts by the Program Executive Office for Mine and Undersea Warfare, (PEOMUW) Indian Head, MD.

TRANSITIONS

Two separate transitions are in progress: a) provide a new section on mine burial in the Mine Warfare Environmental Pocket Handbook, and b) provide source code of the Vortex Lattice Model for the Ocean Atmosphere Model Library (OAML).

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